TMS Arterial Signalization Business Plan

December 2002

A. Introduction

The California Department of Transportation (the Department) has developed a Transportation Management Systems (TMS) Master Plan to improve its use of the existing transportation system by harnessing information technology to support productivity improvement management strategies. This Business Plan is one of several underpinnings to that Master Plan effort. In conjunction with the Master Plan, it makes a business case for realigning the Department's approach to ***system management***, increasing the focus on operational aspects of the transportation system with somewhat less emphasis on physical expansion. It marks a significant commitment to improve travelers' experiences by revising day-to-day operational activity to maximize the capacity of the State roads. Central to this improvement is a dedication to improving system utilization. In order to do this, the Department must develop a continual understanding of how well the system is performing and operating, and revise business practices to optimize performance. Figure 1 graphically depicts this approach. While traditional models place system expansion as the primary aspect of the triangle, this model places operational activity as the focus, supported by a solid base of system monitoring and evaluation, and a dedication to maintenance and preservation. It therefore requires full knowledge of system performance for both day-to-day operations and improvement opportunities.

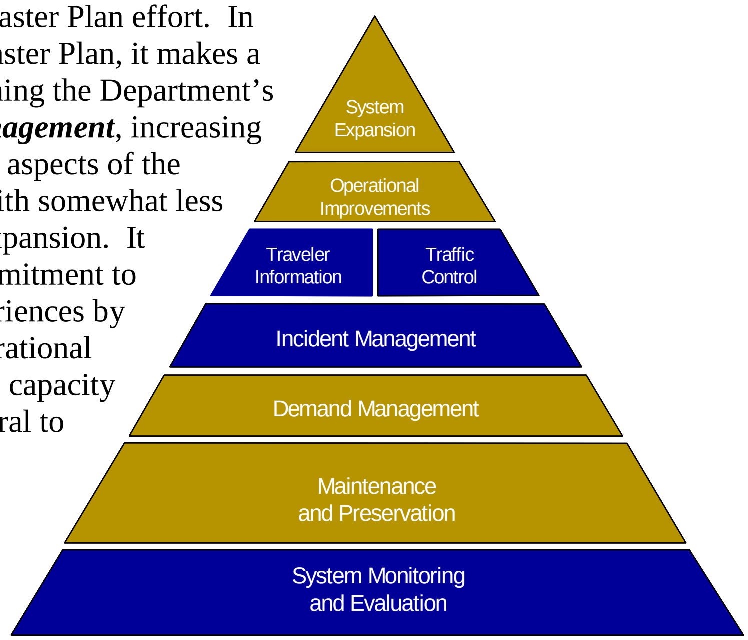


Figure 1

System management is a view of managing the state transportation system as a whole, including all agencies, resources, employees, customers, stakeholders and the infrastructure for the various modes (transit, rail, vehicles). It means that all must work cooperatively, with an organic vision of the whole, to increase effectiveness.

Transportation management systems (TMS) are the business processes and associated hardware and software tools, field elements and communications networks used to manage the flow of traffic. To implement system management, the Department will use operational strategies (both supply and demand) supported by TMS first, then, as appropriate, explore and implement physical operational improvements like an auxiliary lane, and undertake system expansion.

To be successful, all involved must embrace this system management as the long-term goal, and begin to plan within an integrated framework: sound performance assessments, rigorous analysis of proposed improvements, and prioritization of investments. Transportation plans must become broad system management plans with elements addressing operational strategies, maintenance management, and system improvements. For the Business Plan activities enumerated herein to be successful they must be comfortably incorporated in such regional plans. Figure 2, below, demonstrates how system management incorporates management across modes, jurisdictions and functions. For a broader discussion of this concept see Appendix C.

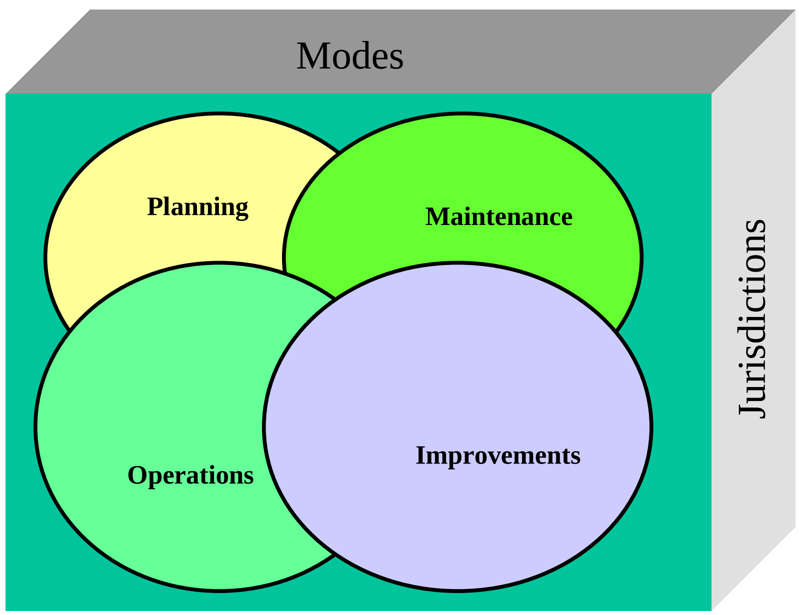


Figure 2

Embracing a system management approach requires a fundamental shift in the way that the Department conducts itself and how it relates to its partners. The Department and its partners must begin to make decisions that are focused and based on the overall system, and better decisions require better data and communications. The Department has evaluated individual business process areas and identified ways that each of these process areas must be re-aligned. For the business of arterial signalization, there are three major areas of change. The Department must:

- devise and implement system approaches that incorporate all key parties into real management teams
- advance the state of arterial signalization statewide to the point that it demonstrates true state of the art in arterial signalization
- improve our tools to enable better ways for our systems to share data

This plan presents specific action steps that are required to accomplish these goals.

B. *Arterial Signalization and System Management*

Many Californians, particularly in urban areas, envision our major freeways if asked to picture a state-owned roadway. They may be less aware of the myriad non-freeway roads that the State also maintains and manages. Frequently, these roads run through our cities and towns and are known to the general public only by their "local" name. For example, 16th Street in Sacramento is in fact State Route 160. Van Ness Avenue in San Francisco is Route 101, and Beach Blvd in Orange County carries a Route 39 designation as part of the State System . There are very visible aspects to the maintenance and operation of these roads, such as the paving and striping. There are less visible aspects as well, such as the way traffic on these roads is controlled.

The Evolution of Arterial Management

To understand the complexities of improving arterial signalization, it is important to understand the progression of signal control technologies. Initially, signal control was accomplished through pre-timed strategies. In a pre-timed environment, detailed traffic studies were conducted and specific timing for each phase (green, yellow, red) of a signal was developed. In this environment, the length of a green light on each side of the intersection is fixed and does not vary. We have all seen the outcomes of this approach wherein a light turns red forcing us to stop even though there is no vehicle on the intersecting road to take advantage of the green. This strategy is still employed in many places throughout the state. As arterial signalization technologies and strategies evolved, actuated signals were developed. This strategy involves the use of detectors, usually inductive loops buried in the roadway, to "tell" the traffic signal there is a vehicle present at the intersection requesting passage.

Actuation strategies can be semi-actuated or fully-actuated. Semi-actuated usually means that at least one, but not all, of the signal phases function on the basis of actuation. As an example, the minor street in an intersection has detection on it and the signal on the main street will stay green until a vehicle is detected on the minor street, at which point the minor street would be given a green light. Fully-actuated means that all approaches to the intersection use detectors to communicate to the traffic signal whether there are vehicles near the intersection. Nonetheless, given the way the Department currently implements arterial signalization even fully-actuated arterial signalization treats each block in isolation from others. That is, the vehicles that are moving down a street are only recognized by the signal control software when a vehicle drives over the inductive loop at an intersection. Although coordination of signals is common on arterials, there is very limited predictive management of the traffic. Large groups of vehicles, such as are encountered during rush hour, are not managed as effectively as they could be under more sophisticated strategies which would take into consideration the traffic along several blocks.

Because these intersections usually involve not just state-owned roads but roads owned by city or county jurisdictions, the determination of what strategy to use and how to use it requires that the Department work very closely with the local jurisdictions. Departmental actions have a very direct, immediate impact on the flow of traffic through a city. Development of appropriate arterial signalization strategies and agreements generally means that all stakeholders (the Department, county and city governments, and regional planning organizations) must develop a consensus that balances the overall needs of all and best meets the goal of improving traffic flow through the area. These negotiations are often very difficult and time-consuming, since each stakeholder can have very different needs and goals. In addition, in districts with numerous jurisdictions, the specific goals of each jurisdiction may be different, even in adjoining jurisdictions, further complicating the process.

There are some efforts underway to implement sophisticated traffic management strategies. In Northern California, the Silicon Valley Smart Corridor Project involves twelve state, local and regional agencies in the implementation of strategies to improve traffic flow on a specific group of roadways and highways. In Southern California, the Southern California Priority Corridor Showcase implements a shared communication capability both intra- and inter-regionally. Appendix B provides overviews of these projects.

As the population of California increases, the demands on the arterial system will increase. In order to continue to maximize the value that Californians receive from their investment in these streets and roads, it is imperative that the Department aggressively work to increase the productivity of the arterial system in a way that balances the needs of the local jurisdictions with the need to meet consumer needs.

C. What is the future of Arterial Signalization at the Department?

The TMS Master Plan is fully implemented and each region has a Regional System Management Plan that fully defines the specific strategies used by the Department and its partners to reduce delay and congestion to the greatest extent possible. Travelers enjoy roads where local jurisdictions and the Department work cooperatively to minimize delay and increase safety. The Department's vision for arterial signalization includes:

- Software to support the downloading of new timing plans and active management of the arterial signals is in place in all TMCs and in TMC Support Stations. The software has the functionality to retain numerous coordination plans that address a wide variety of special events. Activating these plans is a straightforward process that does not require staff presence in the field.
- Arterial management systems are interoperable. Local jurisdictions and the Department have implemented software architectures that are open, allowing data from traffic signals and detector stations to be shared easily.
- Platoon management strategies are in place and vehicles are moved as effectively as possible through arterial systems
- The detection system includes mid-block detection in areas where this has been determined to be an important element of traffic control.
- Performance measures are defined and actively monitored by the Department and its stakeholders. Corrective action is taken as needed to ensure that performance targets are achieved.

D. What benefits does this future bring?

Section E, Action Plan, recommends changes to specific process areas so that the future just described can be realized. And, while this future state is appealing, it is important that the financial investment necessary to achieve it be in proportion to the benefits that will accrue. In order to assess the impact of these recommendations and determine whether the improvements merited the investment, a combination of simulation models and extrapolation models were employed. The results were compared to observed traffic conditions in California and around the rest of the country as validation. The benefits were estimated based on a full, life-cycle analysis over twenty years. Benefits are primarily reflective of savings associated with decreased travel time, but also include impacts on vehicle operating costs and emissions.

This effort was extensive and used very conservative assumptions. Table 1 shows the steps undertaken and the assumptions used. The benefits discussed in this section are also conservative and attainable.

Table 1: Steps to Quantify TMS Benefits

Steps to Quantify Benefits	Conservative Assumption (if any)
Selected two routes (I-680 in the Bay Area and I-405 in Orange County) for simulation	Routes were selected to ensure that a less congested route (i.e., I-405) was included so that the benefits are not exaggerated
Calibrated base simulation models and obtained forecasts from regional agency models	
Quantified benefits of individual TMS recommendations and combinations	Safety benefits observed for ramp metering and incident management TMS processes were not addressed by simulations and not included, even though national experience suggests the benefits could be large.
Validated against real-world and reported results in California and the rest of the country	Benefits were validated to be at the lowest range of observed and reported results.
Extrapolated statewide results	Only peak-hour benefits were included, even though many of the congested routes already experience more than one hour of severe congestion. Safety benefits were also excluded from the overall benefits.

Based on the simulation and extrapolation, benefits were identified for the state. Implementing advanced arterial signal actuation strategies provides benefits that exceed the associated costs. However, the highest benefits are achieved when State-controlled arterial signals are integrated with locally controlled arterial signals and freeway ramp meters. This requires significant coordination and software integration efforts on the part of the Department and its local partners. The benefit-cost ratio for the associated investments is 4.5 to 1.

E. Action Plan

Achieving the future will require that the Department make significant investment in staff training, infrastructure and coordination. While the full details of all necessary action steps will be defined in each Region, there are some steps which must be initiated to set the needed foundation for advancement. Changing how detection is managed and maintained and instituting a formal systems engineering approach to improving processes and tools are necessary precursors to overall improvement. Detection – understanding how vehicles are flowing – is the single most important element in improving how the system is managed and thus increasing productivity. The TMS Master Plan project included the development of a separate plan devoted to improving the way the Department manages detection. The *TMS Detection Business Plan* describes the needs and action plan. The Action Steps described below presume that the detection necessary to support this plan is in place and available. In alignment with federal requirements, the Department is committed to implementing a systems engineering approach in the definition and implementation of improvements to tools and processes. Determination of future processes has resulted, in part, in functional and business requirements that define Departmental future operations. These outcomes are documented in the *TMS Functional Requirements Document*[1].

Advance Signal Actuation Strategies

Central to the ability of the Department to advance in signalization strategies is the implementation of strategies that move beyond actuation as the means to control signals. A more comprehensive approach must be implemented that evaluates traffic patterns across consecutive intersections and determines the most effective signal cycles. In addition to the detection build-out needed for these strategies, the Department must complete other actions. It is important to realize that while the Department can position itself to work more effectively with local jurisdictions, without regional cooperation, the necessary changes cannot be accomplished. Arterial signalization strategies must be defined in close cooperation with the jurisdictions that control the cross-streets.

Retire Outdated Software

QuicNet DOS, the arterial monitoring

[1] This document, and other TMS Master Plan documents, can be found on the following website:

system used in Districts 1, 2, 5, 6, 8, 9, 10, and 12, is not a viable product for the Department to move forward because it lacks key functionality and is no longer supported by the manufacturer. Specifically, QuicNet DOS lacks the following functionality:

- Openness to allow ease of integration with other systems
- Logging of user access and errors
- Network-based environment
- Concurrent connections with multiple agencies
- Intersections configured by point and click graphical user interface
- Multiple intersection displays
- Automatic pager for alarms
- Pan and zoom of map
- Automated inventory
- Detector assignments on map
- Intersection pan and zoom
- Cabinet detail view
- Support of AB3418 messages
- Network (TCP/IP) connection to field master

These features are central to the implementation of more sophisticated arterial signalization strategies. Continued use of QuicNet DOS will inhibit the Department's ability to implement system management. Replacement software should be determined based on the specific needs of the District. In regions where a specific product has been selected and implemented by regional and local jurisdictions, that product could be implemented. Where no specific regional mandate exists, QuicNet DOS should be replaced with CTNet. CTNet is a public domain software developed by the Department and programmed in C++ using an Oracle database.

Upgrade Communications to Support Performance Measurement

Implementation of performance measurement strategies for arterial signalization is hampered by the physical limitations of the field masters (devices which facilitate the control of signals). These field masters collect a great deal of data about activity at intersections but it is not retained in a central data base where it can be evaluated. Communication between arterial management systems and the field masters is currently accomplished through dial up connections. The field masters must be upgraded to accommodate continual communication with the arterial management systems, thus allowing the systems to capture and retain data. With this change, the Department can begin to immediately collect data vital to the development of the arterial signalization performance measurement baseline.

Prepare for Predictive Control Strategies

Advanced signal management strategies such as integration with ramp meters and the implementation of predictive control strategies will require major changes in two areas: additional detection will be required along consecutive intersections so that vehicle speed and traffic volumes can be calculated; and software that can use this information must be implemented. The first aspect, additional detection, is further defined in the *TMS Detection Plan*. The second, software, will require that the Department monitor developments in the software industry and eventually complete a detailed feasibility analysis of the features and functions of available software to determine which software best meets the user, business, functional and technical requirements of the Department. Research in this area is continuing, but full implementation of functionality of this type will not be possible for many years.

Model 2070 Controller Preparations

There are a number of logistical issues associated with the deployment of the Model 2070 Controller which must be addressed to ensure that the Department is positioned for success. Specifically, a comprehensive review of the Department's planning, design, implementation, operations, and maintenance documents should be conducted to identify and prioritize necessary changes. Additionally, a detailed approach to training maintenance and operations staff must be developed and implemented. Finally, a thorough test of all software that will interact with the Model 2070 Controller should be conducted to verify that no adjustments to the software are needed based on the newer technology.

Share Jurisdictional Data

By its nature, arterial signalization requires that the Department coordinate with local jurisdictions. To maintain efficient flow of traffic, the phase timing of Departmental signals must be orchestrated with that of adjacent lights. Optimally, the signal control systems should share data so that system determinations of timing are possible. As an interim step, arterial signalization effectiveness can be increased when the Department is able to see what is going on with local jurisdiction signals and vice versa. Eventually, each entity should have the functionality to actually assume operational control of the traffic signals in either jurisdiction, if necessary and only if all appropriate agreements are in place. Local jurisdictions generally are the driving forces in selection of software to control signals and in some instances have already selected software that the Department staff use. Some local jurisdictions have invested in specific technologies (hardware and software) which are not easily coordinated with the Department's strategic direction. In many instances, the number of intersections where a jurisdiction may have direct interaction with the Department's signals is relatively minor compared to the overall number of signals under its control. In addition, the Department and local jurisdictions have not yet fully implemented standards that would facilitate this interaction. For example, existing law requires that new installations or upgrades of traffic signals must accommodate two-way communication. However, since this law only became effective in January 1996, many signals remain which have not been upgraded to this standard. Variances in the hardware and software used by the Department and the local jurisdictions impact the ability of the various parties to coordinate and integrate signal operation to the greatest extent possible, leading to the need to make changes in the way the Department and its partners share data. There are two areas that require action:

- Implementation of Arterial Management Systems that are Interoperable
- Exchanging Data Between ATMS and Arterial Management Systems

Implement Arterial Management Systems that are Interoperable

The Department has deployed approximately 5000 signals at intersections across the State, out of an estimated 40,000 statewide. The Department is not the prime force behind signalization issues statewide and cannot dictate to local jurisdictions what software must be used. Further, in some instances, it is more cost-effective to allow Districts to implement software that has been chosen by the local jurisdiction. For example, District 11 works very closely with the San Diego Association of Governments and the City and County of San Diego. Within this region, entities that operate signals have agreed to use the same arterial management system: QuicNet 4. District 11's use of QuicNet 4 results in easier coordination with local signals, reduced training costs since staff only learn one system, and an increased capacity to collaborate on problem solving.

District 4 (San Francisco Bay Area) has also been very successful in working cooperatively with numerous jurisdictions to create a seamless management approach. Working with the Alameda Congestion Management Agency, the Department has implemented CTNet in numerous cities, including Oakland, Emeryville, San Leandro and Berkeley, allowing the participating entities to view each other's signal timing patterns and monitor system operations. These two examples demonstrate the benefit from the implementation of the same software throughout a region.

Unfortunately, such unanimity is not in place everywhere, and in some Districts, including District 4, there are numerous software systems in use by the local jurisdictions. These software are not directly compatible with each other and so data sharing, and eventually shared operational control through downloading of preset timing patterns, is extremely difficult. In some areas, local jurisdictions have permitted District staff to access the software to view information about the signals, such as timing patterns. While this is helpful in the management of the system, District staff must learn how to log on to and maneuver through several different software programs in order to view what is going on with its partner agencies' signals. The processes are cumbersome and do not address data sharing.

In instances where such intra-regional coordination is lacking, or where inter-regional coordination is needed, data sharing approaches must be employed. The Department must evaluate the success of data exchange projects such as Showcase in Southern California and determine whether it can be applied to these areas.

Exchange Data Between ATMS and Arterial Management Systems

Central control, the ability to set and change timing patterns from a location like a TMC, is an essential element in improving arterial signalization strategies. Without central control, arterial signal timing patterns can only be adjusted by staff at the controller cabinet at the side of the road. Without central control, for example, special events such as baseball games or large community events, require staff intervention at the controller in the field to adjust the arterial timing patterns around the impacted area.

The Department's Advanced Transportation Management System (ATMS) is a component-based system that allows operators to manage the State highway system remotely, including the control of ramp meters. CTNet and QuicNet 4 are arterial management systems used to manage the arterial signals. Effective system management depends on distribution of relevant information to all those involved in traffic management so that traffic managers are able to see conditions impacting traffic overall and use that information to inform their decision-making processes. In particular, providing arterial signalization staff the ability to view ramp meter timing patterns so they can determine if adjustments are necessary is an important step in improving the productivity of the system overall. The reverse is also needed, so that ramp metering staff can review arterial signalization timing patterns. Currently, the Department staff can access the arterial management systems and ATMS through an integrated work station, allowing the operators to see the timing patterns in use.

Eventually, though, information from arterial subsystems will be sent directly to the ramp metering subsystems, and vice versa, and timing patterns of each will react to the data that is shared. When each of the subsystems is able to receive data on the progression of vehicles through the network, and with the appropriate algorithms to interpret and predict the impact of the traffic, flow can be optimized through the network. While the algorithms to implement this integrated, adaptive control strategy are not yet fully developed, the Department subsystems must be planned and positioned to accommodate this functionality when it is available. The Department must monitor and participate in the research necessary to develop and test this functionality. Additionally, as noted in the *TMS Detection Plan*, the detection network on the arterials must be expanded so that mid-block volume and speed data is available. This data is critical to the implementation of integrated adaptive control strategies and the management of large platoons of vehicles moving through consecutive blocks.

Develop Knowledge Management and Experience Leveraging Mechanisms

This action step focuses on defining the mechanisms needed to ensure that the Department staff have access to the information that they need to do their jobs the best possible way. To enable this, the Department needs to develop a knowledge management system and create mechanisms to leverage the significant experience that the Department staff possess.

Knowledge Management System: A knowledge management system is designed to make it easier for staff of an organization to access information that will help them perform their jobs better. The content of a knowledge management system varies based on the needs of the organization. For ease of access, the system should be distributed over the web and accessible through a standard browser interface. Minimally, the system should contain all policies, procedures, regulations and guidelines that govern traffic operations. When new documents are added to the system, an e-mail notification should be sent to all staff advising them of changes and instructing them to review them. Given the increasing interconnectedness of planning and maintenance with traffic operations, consideration should be given to including the same types of documents from planning and maintenance. In addition, the knowledge management system would house the outcomes of the experience leveraging activities described below.

Within the Department, there is need for better access to policies that govern and define the roles and responsibilities between and among local jurisdictions and the Department. For example, the Department permits a local jurisdiction to install emergency vehicle pre-emption on an arterial signal, but staff reported that it is unclear which entity is legally responsible in the event of an equipment malfunction. In issues such as this, there is no centralized source for staff to access this information. Staff are also operating on varying interpretations of policies. A knowledge management system will provide the staff with easy access to up-to-date information central to their jobs.

Leveraging Experience: Taking the lessons learned in one situation and applying the knowledge to another situation, is a valuable way for organizations to increase the likelihood of success in endeavors. Some districts have been extremely successful in developing strong inter-jurisdictional partnerships. The knowledge and experience gained through these efforts should be maximized by deploying the documented experiences on the Knowledge Management System. As successful practices are shared and used by other districts, the overall effectiveness of organization will increase.

A team should be tasked with conducting a review of inter-jurisdictional outreach efforts. The initial review should be aimed at determining, among other things:

- What constitutes a successful inter-jurisdictional relationship
- How the complexity of multiple jurisdictions with very different viewpoints impacts the inter-jurisdictional relationships
- What good practices have already been developed and implemented by the Department districts
- What types of materials, print or other media, are available now within the Department that should be collected and disseminated to others
- What policies are pertinent to arterial signalization and whether these policies continue to provide value
- What latitude the districts have in determining how to respond to local jurisdictions and when should headquarters be involved
- What specific lessons can be learned from the experiences of the Priority Corridor, Silicon Valley Corridor, and other initiatives

The team would also create guidelines to help districts in their interactions with local jurisdictions. The guidelines would include:

- Detailed plans on how jurisdictions can share information
- Encouragement for the jurisdictions to coordinate with one another
- List of steps to be recommended (or avoided) that could lead to effective procedures to avoid delay and congestion.
- Sharing experience between Districts and local jurisdictions

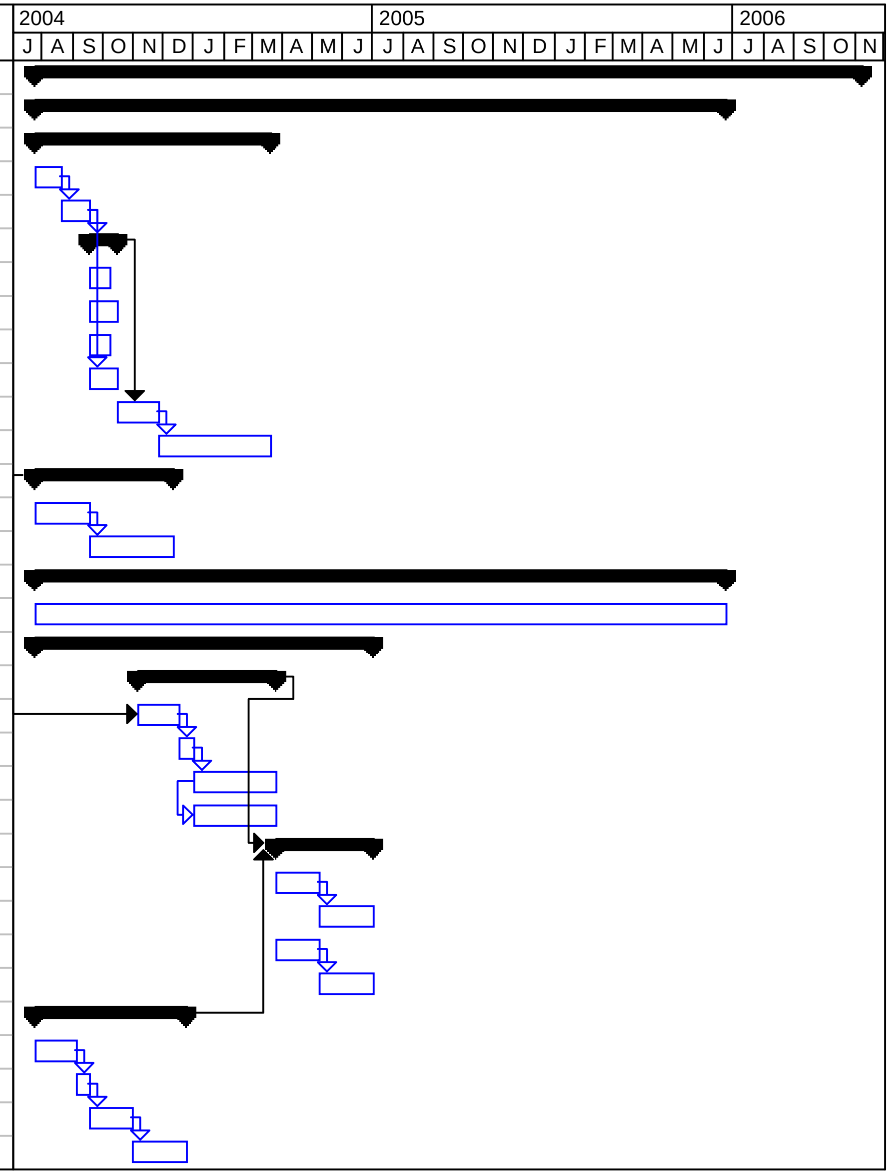
- Specific policies applicable to arterial signalization

F. Implementation Schedule

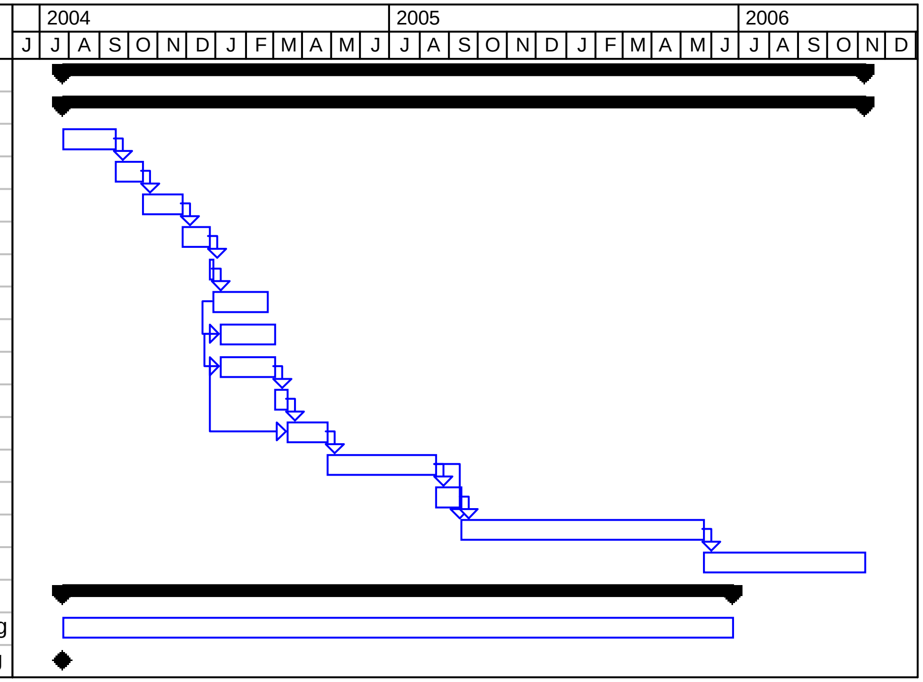
To help the Department plan and implement the recommendations provided in the Action Plan, preliminary schedules have been developed which can be used as the basis for more detailed planning. The schedule provides dependent relationships, identifying those tasks that require input from another task. Using the cost-benefit results, these tasks were prioritized in the larger context of the overall TMS project. The project plan below reflects that prioritization. It is important to note that the efficacy of the overall arterial signalization effort is directly dependent on the implementation of the field elements that support it. Therefore, while software systems maybe completely developed and in use in some areas, the full spectrum of data statewide may not be available when the software is implemented. Please refer to the *TMS Master Plan* for a complete schedule, including TMS element deployment timelines.

The durations are reflective of elapsed time to complete the tasks, and are not directly reflective of the number of staff hours or level of effort to complete a task.

ID	Task Name
1	**Arterial Signalization Action Steps**
2	**Advance Signal Actuation Strategies**
3	**Retire Outdated Software**
4	Meet with impacted Districts
5	Determine overall timeline (when will each District be converted)
6	**Define transition plan**
7	Define staffing impact at District and HQ
8	Define hardware impact (desktop and servers)
9	Define software impact
10	Define training plan
11	Implement training plan
12	Implement transition plan
13	**Upgrade Communications to Support Performance Meaurements**
14	Develop upgrade plan for each district
15	Implement upgrade
16	**Prepare for Predictive Control Strategies (On-going)**
17	Continue research.
18	**Model 2070 Controller Preparations**
19	**Documentation Review**
20	Review internal policies, procedures, guidelines and manuals
21	Create review and revision timeline
22	Review and revise documents
23	Create new documents as needed
24	**Staff Readiness**
25	Develop training plan for maintenance
26	Implement training plan for maintenance
27	Develop training plan for operations
28	Implement training plan for operations
29	**Software Preparedness**
30	Develop software testing plan
31	Define software testing environment
32	Implement software testing plan
33	Mitigate as needed



ID	Task Name
34	**Share Jurisdictional Data**
35	**Implement Arterial Management Systems that are Interoperable**
36	Meet with Locals to secure support
37	Determine overall timeline
38	Define Working Committee that includes staff from Districts and local partners
39	Determine what software will be considered in the scope of the project
40	Meet with Configuration Control Board
41	Define user requirements
42	Define functional requirements to meet user requirements
43	Determine and document specific standards that will be used
44	Configuration Control Board approves project
45	Develop FSR and request funding
46	Await approval
47	Develop RFP for vendor
48	Acquire vendor
49	Vendor completes work
50	**Exchange Data Between ATMS and Arterial Management Systems**
51	Continue with research on integrated network technologies and algorithms (ongoing
52	**Develop KMS and Leverage Experience: Task Completed Jointly with Ramp Metering**



G. Performance Measures

Overview of the Performance Measurement Framework Effort

As part of the TMS Master Plan effort, performance measures have been developed to support each business area. The following section presents a summary of the arterial signalization performance measurement framework.[2] Leveraging past work in the area, the Department's System Performance Measures initiative was used as a starting point for identifying indicators for each TMS. These outcome-based indicators, developed and analyzed over the last few years, represent the foundation for communicating the performance of the multi-modal transportation system to customers and decision makers. Each indicator was evaluated to determine how the TMS Master Plan might impact it. Table 2 presents the outcome categories that are most affected by TMS strategies and candidate indicators for consideration.

Table 2
Department System Performance Metrics

Outcome	Definition	Candidate Measures/ Indicators
Mobility / Accessibility	Reaching desired destination with relative ease within a reasonable time, at a reasonable cost with reasonable choices	• Travel Time • Delay • Access to the Transportation System
Reliability	Providing reasonable and dependable levels of service by mode	• Variability of Travel Time
Cost Effectiveness	Maximizing the current and future benefits from public and private transportation investments	• Aggregate Indicators (e.g., Benefit-Cost Ratio) • Disaggregate Indicators (e.g., Cost per Annual Person-Hour of Delay, Cost per Accident, etc.)
Environmental Quality	Helping to maintain and enhance the quality of the natural and human environment	• Federal Regulatory Standards for Specific Pollutants • Community Noise Equivalent Levels (for aviation)
Safety and Security	Minimizing the risk of death, injury, or property loss	• Accident Rates • Crime Rates

[2] Please refer to the TMS Performance Measurement Framework for complete details. The document can be found at the following website:

Outcome	Definition	Candidate Measures/ Indicators
Customer Satisfaction	Providing transportation choices that are safe, convenient, affordable, comfortable, and meet customer needs	• Customer Satisfaction Index

The indicators for each TMS are categorized based on their target audiences as follows:

- **External Stakeholders** – traveling public, external agencies, legislature
    - Focus on real world results
    - Less detailed, more macro results
    - Statewide/regional trends
- **Management** – the Department, CTC, other transportation agencies
    - All results provided to external stakeholders
    - Before and after results of TMS implementations
    - More detail, not too technical
    - Statewide/regional/corridor trends
- **Practitioners** – staff in charge of day to day operations of the TMS
    - All results provided to external stakeholders
    - All results provided to management
    - Detailed technical results
    - Spot specific results

There are several factors that influence when a specific performance indicator will be available to its target audience. Generally, data and analytic tool availability are the major factors that influence whether a specific indicator's implementation timeframe is considered to be 'short-term' or 'long-term'. It is important to understand that all indicators will eventually be used for reporting.

Specific Arterial Signalization Performance Measurement Framework

Recommended arterial signalization performance measures for external stakeholders are outcome-based, high level and aggregated. Table 3 summarizes the proposed indicators to use and distinguishes between short term and long term implementation timeframes.

Table 3
Arterial Signalization Performance Measures for External Stakeholders

Outcome	Indicator	Implementation Timeframe
Mobility	Delay on arterials	Long
	Duration of congestion on arterials	Long
Reliability	Variability of travel time by major origin destination including arterial travel.	Long
Productivity	Flow rate by major origin/ destination pair	Long
Customer Satisfaction	Customer Satisfaction with deployed strategies	Long

Performance indicators for the management stakeholder group include two additional indicators over and above the ones recommended for external stakeholders.

Table 4
Arterial Signalization Performance Measures for Management Stakeholders

Indicator	Strategy States	Implementation Timeframe
Percent of arterial signals operating in different strategy states	• Fixed time • Actuated • Advanced adaptive (incorporates mid-block detection data) • Integrated with local arterial management systems • Integrated with ramp metering	Short

Finally, performance measures for practitioners require additional detail for the flow rate and signal wait times indicators. Practitioners will need signal by signal data to monitor and evaluate the system and make adjustments as appropriate. All of these indicators require further analysis and tool development before they can be implemented statewide and therefore have a long-term implementation timeline.

Table 5
Arterial Signalization Performance Measures for Practitioners

Outcome	Indicator	Implementation Timeframe
Mobility	Wait times at each arterial signal	Long
Productivity	Flow rate at each arterial signal	Long

Specific targets for performance improvement will be developed for each indicator.

H. Cost

The table below presents preliminary cost estimates to implement the action items defined in this plan. These costs do not reflect any cost sharing between business plans, so those action items that appear in more than one plan are fully costed in each plan.

Action Step	One-time Cost	Annual Cost
Retire Outdated Software & Upgrade Communications to Field Masters	181,000	180,000
Model 2070 Controller Preparedness	204,000	N/A
Implement AMS that are Interoperable [1]	10,200,000	1,191,200
Exchange Data Between ATMS and Arterial Management Systems	150,000	46,500
Develop Knowledge Management System & Leverage Successful Practices	1,068,620	86,400
Implement Mid-block Detectors	50,000,000	3,000,000
Total	**$ 61,803,620**	**$ 4,504,100**

Appendix A:

Showcase and Smart Corridor Project Overviews

The Southern California Priority Corridor Showcase

The Southern California ITS Priority Corridor covers portions of six counties and four Departmental Districts in Southern California. The primary purpose of the Showcase Projects is to optimize and coordinate transportation management within the corridor. This is accomplished by sharing transportation data and the development of coordinated incident/event response between the Transportation Management Centers (TMCs) of the partner Transportation Agencies. The partners include the Department, Metropolitan Planning Organizations (MPOs), counties and cities in Southern California. Projects are spread across the Southern California area and include: TravelTip (Orange County); IMAJINE and LA/Ventura Regional ATIS (LA and Ventura Counties); Fontana/Ontario ATMIS (San Bernardino and Riverside Counties); Mission Valley Stadium ATMIS, SD Traffic Signal Integration, San Diego Transit Management, San Diego ATMSi (San Diego).

Data shared primarily includes freeway and arterial congestion (volume, occupancy, speed) and freeway and arterial incident data (accidents, incidents, closures), event data (sports, natural disasters), and transit data (bus and train route and schedule). Coordinated incident/event response provides pre-approved local response to incident/events originating in another geographical or functional jurisdiction. Shared device control includes but is not limited to items such as Closed Circuit Television Cameras (CCTV) and Changeable Message Signs (CMS).

The data is shared via a common computer network called the Showcase Network. This network includes the leased communications lines, routers and servers necessary to connect all the partners onto the common network. This network provides the conduit for the partner agencies to share data. The Showcase Network includes the computer **servers** (called Kernels) and the **interfaces** to each of the partner agency systems and projects (called Seeds). In addition to the communications, the Showcase Network provides a suite of services common to all the projects such as security (verifying only appropriate partners are connected) and naming (a complete listing of all partner field devices available such as closed circuit television cameras (CCTV) and changeable message signs (CMS)). The basic communications and the servers are called the “core” system.

The Silicon Valley Smart Corridor Project

The Silicon Valley Smart Corridor project is a program that implements ITS elements in the I-880/SR 17 corridor. The corridor includes a major north/south freeway facility leading from Santa Cruz County in the south to downtown San Jose, the San Jose International Airport, and major Silicon Valley and East Bay employment centers to the north. In addition the corridor includes a number of major north/south roadways. The parallel roadways carry large volumes of through and local traffic, and serve as overflow routes when the freeway is overly congested due to incidents.

There are twelve various local, regional, and state agencies involved in this project. Traffic signals within the corridor are under State and local jurisdictions. There is an existing agreement between all different agencies including a control plan during unpredicted traffic congestion. Prior to this project, traffic signal coordination between jurisdictions was very limited. The Smart Corridor project attempts to link all of the transportation management centers and allow greatly improved sharing of information among the various jurisdictions. To facilitate the sharing of information, a number of different systems were planned for deployment along the corridor. These systems include: closed circuit television traffic surveillance, message signs, coordinated signal timings, and sharing of the communication infrastructure. The goals of the corridor improvements identified by the project participants include:

- Minimum intrusion of freeway traffic onto local streets due to freeway congestion and freeway incidents
- More rapid response to and clearing of incidents on both the freeway and surface streets
- Active management of traffic already diverted from the freeway and surface streets
- Improved traffic signal coordination that is responsive to fluctuations in demand
- Improved collection and dissemination of current travel condition information
- Coordination of these activities between agencies
- Sharing resources among agencies

Arterial signalization capabilities are provided by the integration of 26 individual signalized intersections, which are operated by five separate jurisdictions.

An important part of the plan incorporates a coordinated operation system during incidents. In the event of an incident on the freeway, the

Smart Corridor Plan will be activated and components are operated as an integrated system to lessen the impact of the non-recurring congestion. If the traffic diverting onto the arterials is deemed significant, there are several different strategies that may be implemented. An important element is the integrated operation of all signals along the corridor according to a coordinated plan designed to "flush" the added traffic that diverts from the freeway by borrowing green phase time from the cross streets.

Appendix B:
Arterial Management Systems

Arterial Management systems (AMS) are used to manage and control traffic on arterial roadways, allowing for central or remote control and monitoring of arterial traffic signals. In some cases, the AMS have additional functionality that includes control over other elements, such as CCTV, CMS, etc. They can also provide a detour plan for either arterial or freeway traffic in case of planned or non-recurring traffic congestion. They also enable cooperative management of signals between state and local agencies. There are two primary AMS used by the Districts and some local agencies to monitor and control the signalized intersections: CT Net and QuicNet 4. CTNet has been developed by the Department and is therefore public domain software. QuicNet 4 is proprietary software produced by a private firm. Each of these systems provide information and functionality that allows staff to remotely:

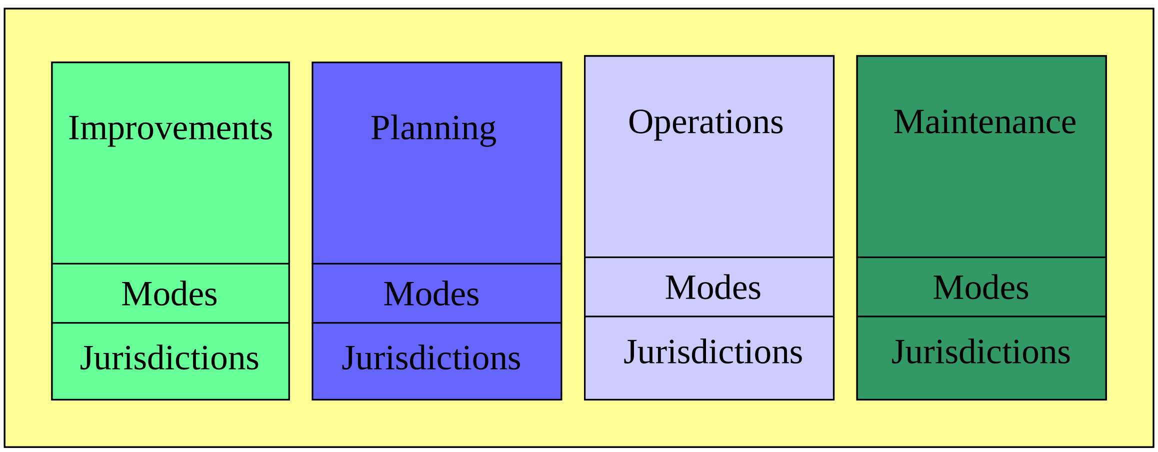
- Verify that the intersection controller and field master have the proper day, date, and time
- Verify that intersection detection is functioning properly and remotely reset detector if necessary
- Confirm that an intersection is not dark (due to power outage or blackout) or on red flash
- Check local controller timing parameters and set, upload or download new timing if necessary
- Check field master controller timing parameters
- Temporarily change signal timing to aid construction and maintenance activities when affecting the normal signal operations
- Make permanent adjustments
- Upload alarms for review of system operations

Many Districts are not currently using an AMS, but instead use a traffic signal surveillance system called QuicNet DOS. This system allows staff to view timing and status of detection as well as download changes as necessary. Local jurisdictions use other software for arterial management including ICON, Naztec Streetwise Systems, Transcore Service 2000, and Bentley. Some of these software packages interface with the Department AMS to exchange signal data, video information, data from system detectors, etc.

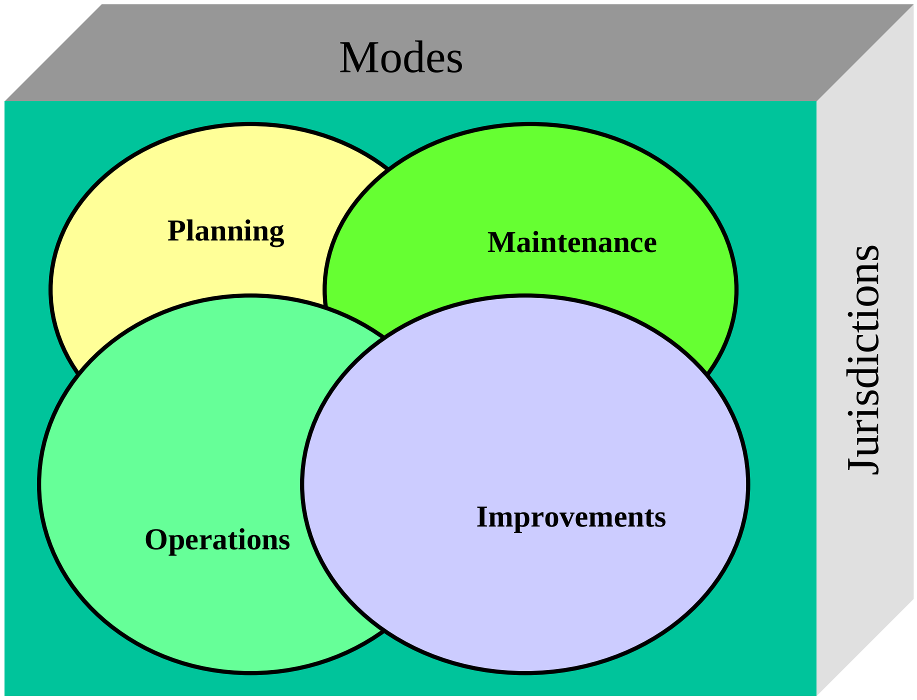
Appendix C:

Regional System Management Plans

Coordination and cooperation between the Department, regional (e.g., MPOs, regional government associations), and local agencies is critical in the implementation of system management. The Master Plan effort has helped coalesce for the Department the need to move beyond traditional silos of activity to a more organic approach to planning and operations. As demonstrated in the graphic below, the Department has conducted planning largely in isolation from operations, and the individual elements have also been planned and operated in isolation.



System management, on the other hand, demands that planning and operations, as well as maintenance and improvements be viewed cohesively as aspects of traffic management along a continuum. Planning activities must be informed by operational considerations, and operational considerations must use planning to maximize the effectiveness of the operations.



A comprehensive detailed plan must be developed with the customer perspective as the driving force. One of the factors that has impeded the progress of system management in California is the myopic perspective many of the key stakeholders have adopted in the past. Local jurisdictions, understandably, focus on satisfying their constituents and on the issues under their immediate control. Unfortunately, this can manifest itself in local jurisdictions refusing to allow the Department to implement ramp metering strategies because they want to discourage commuter traffic on local streets. Congestion, though, is not bounded by jurisdictional lines, and Californians increasingly travel longer distances from work to home. Inter-jurisdictional travel is the norm in California, and detailed system management plans must be developed to address this reality.

At the regional level, a cross-functional team led by the MPO and including representatives of the Department and local jurisdictions must be established. These staff should be involved in planning, operating and maintaining arterial signals and ramp meters, and incident management. This team must plan and implement the interaction between freeways and all parallel arterials, regardless of what agencies operate them.

This plan should include:

- Establishing expectations for management for every day congestion and provisions to deal with non-recurring congestion

- Defining the protocols for coordination and sharing of data between jurisdictions
- Ensuring that all parties have access to the data necessary to fully implement the plan
- Defining the specific ramp metering strategies that will be employed by corridor, with specific emphasis on reaching agreements with local and regional entities on the implementation of corridor-wide adaptive ramp metering
- Defining arterial signalization strategies between and among the jurisdictions
- Determining the most appropriate timing patterns to coordinate arterial and ramp meter signals
- Establish diversion standards including:
    - Establishing policies and procedures to identify and develop preplanned diversion routes, including the activities to operate and coordinate the diversion scheme
    - Reviewing, analyzing, and planning diversion responsive coordination of traffic signals along the diversion
    - Conducting traffic simulation and modeling studies needed to review and evaluate alternative diversion routes
    - Reviewing and analyzing the impacts diversion routing has on arterials

To support the planning efforts, the Department should encourage and promulgate the use of simulation technology, including providing training and support to the Department, local and regional staff. New traffic micro-simulation technologies have highly disaggregated modeling capabilities that allow for testing detailed traffic control strategies before they are implemented in the field.

The team should formally document processes and procedures that will support the implementation and maintenance of the management efforts. This document should include areas such as installation, maintenance, operations, emergency management, etc. The team should also document stakeholder expectations in areas that have the potential to conflict, such as how the ramp meter will react to back-up of traffic onto arterials, diversion routes when the freeway is closed or significantly congested, whether travelers should be encouraged to use parallel arterials as alternatives to freeways, etc. Equally as important as establishing these expectations is defining the process that will be used to periodically review the expectations to determine if they are being met and the process that will be used to revise them.

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